A GIS Based Referral Planning System

Jibanananda Roy
Institute for Planning Innovative Research, Appropriate Training and Extension GC-1, Salt lake, Kolkata, India, 700106
E-mail: jibroy@eth.net

Chandreyee Das
Institute for Planning Innovative Research, Appropriate Training and Extension GC-1, Salt lake, Kolkata, India, 700106
E-mail: chandreyee@inspiration-india.org

ABSTRACT

Referral System is one of the important aspects of efficient Public Health Care Delivery mechanism. Referral system defines processes for effective use of multi-tier system of health centres and hospitals for treatment of patients according to the severity of illness. Complicated cases beyond the scope of treatment in a particular facility are referred to a technically equipped higher tier hospital following a definite referral chain designed on the basis of distance and facility- availability criteria. Such a system has been introduced in most of the states of India within various administrative units. However, the outcome of this system is mixed in terms of compliance and non-compliance to the defined hierarchical pattern of referral due to a number of factors ranging from awareness, spatial and supportive logistics and socio-economic conditions of the beneficiaries. This is particularly relevant in areas with a difficult terrain, where spatial factors and socio-economic conditions play a decisive role in complying with the suggested referral chains to the pre-defined hierarchical health units. Thus planning for an adequate health system with an efficient referral mechanism requires a combination of facility and spatial analysis to derive an optimal service delivery system. The present work uses GIS as a useful tool for decision support planning considering the incorporation of spatial and non-spatial data in a single reference frame. Sunderban region of India has been chosen as a case study area. The present state of health referral system is devoid of specific spatial considerations except for crude nearness estimate between the source and the destination health centers. While this absence of detailed spatial considerations may be acceptable for urban, semi-urban or even mainland rural areas that enjoy a good connectivity by rail & road; it is a cause of grave concern for arduous terrains like the Sunderbans where free movement between a source point to a destination health center often gets heavily impaired due to spatial limitations. In this paper a Network Optimization model based on several spatial as well as non-spatial factors to minimize an integrated cost function has been proposed. The optimization model analyzes several routes from one health center to another center using road, river or a combination of road and river depending on several factors like disease condition, severity of disease, season, time, socio-economic condition, etc. The study thus attempts

to formulate a health-system-aware and terrain-sensitive referral strategy that would take the significant spatially dominant factors into due consideration. The overall strategy is formulated as an optimization problem where, initially, every health center is considered an equally potential referral candidate for any patient originating from any village in the region and having any possible complaint or condition. A set of feasibility constraints is overlaid on the whole set to prune out a smaller subset that qualifies as one of the viable referral points. Finally, a composite cost function that computes the economic, temporal, qualitative and other variant costs, makes a choice of the ‘ideal’ referral point that minimize the cost and therefore, maximizes benefits.

INTRODUCTION

Referral system, the basis for efficient public health care delivery mechanism has been designed and introduced with an aim to link up preventive, promotive, curative and specialized care services for management of patients according to the degree of severity of illness through the multi-tier system of health centres and hospitals. Complicated cases beyond the scope of treatment in a particular facility is stabilized first with appropriate medical care and then promptly referred and transferred to a technically equipped higher tier hospital by following a definite referral chain**.** The basic concept of a referral system is to emanate from lowest level and to end in the tertiary care facility.

The referral system planning involves two decisions

- Deciding on the referral protocol
- Deciding on the referral chain

While referral protocols contain administrative guidelines, facility, equipment and service norms, referral chains**,** at present, are designed based on primarily two criteria

- Distance and
- Availability of required service facility at the nearest point following the hierarchical pattern of health care delivery

The referral mechanism has been introduced and made functional in most of the districts but are providing mixed results in terms of compliance and non-compliance to the defined hierarchical pattern of referral. The characteristic of referred cases reveal the following

- Patients often do not reach the appropriate health facilities
- Patients most often do not reach health facilities in time
- Patients often do not follow the referral advice
- Patients bypass lower level health facilities, unnecessarily overcrowding the higher level hospitals

As identified, this has been due to a number of factors ranging from inadequate knowledge of providers and takers, lack of confidence of beneficiaries on government services, inadequate infrastructure and logistic facilities coupled with barriers of problematic terrain vis-à-vis distance, transport and conveyance facilities and associated costs to reach the designated referral facility tied up in referral chain and this is extremely relevant in areas with a difficult terrain like the Sunderbans and the Hilly Districts of Darjeeling or mixed terrain areas of the Duars in West Bengal, India.

Thus planning for an adequate health system with an efficient referral mechanism requires a combination of facility analysis along with a spatial analysis to arrive at an optimal service delivery system and GIS could be a useful tool for decision support planning considering the incorporation of spatial and non-spatial data in a single reference frame.

The use of GIS in health has been attempted by different agencies in India. Danida-assisted National Leprosy Eradication Programme is one of the foremost in introducing GIS in health in the country [1]. Apart from DANLEP, many development agencies[3,4,5] and government institutions are exploring Health GIS in India. Malaria Research Centre, New Delhi [2], Vector control research center, Pondichherry, UNICEF, WHO for leprosy, TB, malaria and Pulse Polio programmes, HIV/AIDS programmes in TN, Orissa and MP are few recommended studies. However, all these studies aim at developing Health / Disease Maps to aid in facility and preventive planning. An interesting work has been carried out by LN Balaji [4] of NATMO Calcutta using GIS to study the influence of locational attributes on Health conditions and also to determine the nature of disease diffusion across geographic regions. Some research has been attempted on creating Health database and using it as a support for Health Facility Planning. The study by Mili Ghosh. Shantanu Lal and Dr. MS Nathawat of BIT Meshra[6] is on these lines and it provides a facility upgradation plan. So far no attempt has however been made for Referral System Design in India as institutionalisation of the referral mechanism is a relatively new management concept in Public Health Care Delivery System. A somewhat similar study in identifying referral regions based on the service population and catchment area features has been attempted by Dartmouth Atlas of Health Care in the United States.

There is no spatial component in the state health referral system. However, in the arduous terrain like Sundarbans the spatial component has a major role to play while deciding for a referred health center. The major factors, in addition to distance and disease type/condition, are type of road, availability of river route, seasonal dependency, time of the day (day or night for River route), available conveyance type. The main objective of the study is to decide on a Network optimization model based on several spatial as well as non-spatial factors to minimize a cost function. There may be several routes from one health center to another center using road, river or a combination of road and river depending on several factors like disease condition, socio-economic condition, severity of disease, season, time etc. The distance from a village to bust stop, ferry ghat, health center and road/river coverage will be extracted from the spatial layer. Route layer will also be derived combining road layer, river layer, seasonal and time based dependencies. Whenever there are changes in health center availability, new roads and river routes the spatial database could easily be updated and new routes will be derived.

In this paper, an optimization model incorporating spatial and non-spatial data has been proposed for designing an effective Referral system model specific to arduous terrains. The model has been developed considering the geographical spread and terrain characteristics, natural and climatic conditions, seasonal deviation, land use, infrastrutural and service facilities, connectivity and communication network etc and to identify the natural and physical conditions and factors limiting mobility.

STUDY AREA

The methodology proposed here, is expected to be applicable to an arduous terrain where the Referral system is dependent on spatial factors. However, to study and develop a strategy, Sundarbans region have been chosen. The Sundarbans in the eastern part of India and in Southern West Bengal, with a population of more than 3.5 millions spreading over 19 blocks of both the districts of 24 Parganas, is one of the underdeveloped regions in the state with predominance of small and marginal farmers. The 54 islands, interspersed with bodies of water, are covered with forests and swarms. Wide tidal rivers and estuaries and narrow tidal creeks intersect them. Transport and communication networks are inadequate in this hostile geographical and topographical location. People have to travel in an assortment of improvised country boats, cycle-rickshaws and buses to reach their destination, which is extremely time and cost inefficient. There are no major hospitals in the region and travel time varies between 6 to 8 hours to reach Sub-divisional or District Hospitals from the core of Sunderbans. 11 RH-s, 8 BPHC-s and 45 PHC-s are located in the region with 659 SCs. Most of the BPHC-s, PHC-s and SC-s are situated in the riverine area where as RH-s are located at the entry/exit point of the mainland area of Sundarbans. The referral mechanism has been initiated in the Sunderbans but not systemised. Tentative referral chains have been developed. Cases are being referred, most often not following the referral chains, but following the principle of "facility available at the nearest government center/hospital". This however eases the referral procedure to some extent but compliance is still not to the desired extent as terrain specific traversal is further dependent on seasonal conditions as well as availability of communication facilities A significant percentage is also sent to private service centres in order to avoid communication uncertainties.

A study on a representative sample of Gynecological and Obstetric Cases in three selected blocks of South 24 Parganas Sunderbans revealed that in case of patients originating from hospitals, 45% of the cases have complied with the designated referral chain while 55% did not comply. Any pre-defined norm based system of health delivery like the referral system, which may be applicable to different districts of West Bengal may not be applicable in the case of Sunderbans particularly because of its geographical features. Thus planning for an adequate health system with an efficient referral mechanism calls for the design of an interactive and dynamic system for optimal design of referral chains considering the spatial and non-spatial attribute. It requires a combination of facility analysis along with spatial analysis to arrive at an optimal service delivery system and GIS is the most useful tool for decision support planning considering the incorporation of spatial and non-spatial data in a single reference frame.

METHODOLOGY

The Optimization Model

The lack of the ease of mobility due to poor infrastructure implies that the spatial components need to play a major role in deciding on the referral to every referred health center in the Sunderbans. The whole of the referral inference and planning, therefore, must take cognizance of various factors including the ones that are either purely spatial in nature, or influence spatiality in some measure and / or are impacted by one or more spatial factors as given below.

1. Distance

2. Type & Quality of road / connectivity
3. Availability of river route
4. Modes of transport
5. Time of the day (day or night for River route),
6. Seasonal dependency
7. Disease type
8. Criticality condition
9. Service availability etc

The overall strategy is formulated as an optimization problem where, initially, every health center is considered an equally potential referral candidate for any patient originating from any village in the region and having any possible complaint or condition. We then overlay a set of feasibility constraints (service availability constraint specific to a disease, patient instability) on the whole set to prune out a smaller subset that qualifies as one of the viable referral points. Finally, we engage a composite cost function that computes the economic, temporal, qualitative and other variant costs and makes a choice of the 'ideal' referral point that minimize the cost and therefore maximizes benefits. In order keep the option open for subjective judgments that may not be captured in the model (due to lack of data and / or timely update), we generate two or more ranked referral-point candidates and allow for a final human selection.

In the following sections we outline the factors in the cost function and also the spatial and non-spatial representation of information for formulating the candidate set and the constraints.

The Cost Function

The objective of the ***Referral System Design*** activity is to create a Networked Optimization Model based on several relevant spatial as well as non-spatial factors that would minimize the cost functions that hinder the effective use of the referral chain. Amongst various parameters, the cost function would attempt to optimize the following:

Commutation cost

This model describes the distance between any two points, the different modes of transport used and the total cost to reach the destination. For Sundarban, in order to reach a particular point from a given point one has to go by the land or by the river or both.

Thus the distance information is broken up as land distance and river distance respectively. The sum of the above two distances gives the total distance to travel. Like wise the total cost to travel is the sum of the costs to travel on land and the costs to travel by river. Based on the Total time (T_T) and Total cost (T_C) Commutation Details defines a priority index called *Accessibility Index*. Comparing the accessibility indices for the different routes from one point to other one can identify the best possible route in terms of time and cost.

Service availability constraint

The Service Model describes the services rendered by the different health centers. It identifies the name of the health center, its type (i.e., PHC, BPHC, RH, SDH, etc), diseases/ ailments that are treated and the criticality level of the disease that can be handled. For a given patient with a certain level of criticality and originating from a particular location one can determine the possible destination health service centers from the service model.

Distress Factor

Distress Factor is a quantitative measure of the amount of distress or discomfort that one has to bear in order to travel from one point to other. The distress factor for any two points is defined by the condition of the roads, the time in waiting for the availability of transport (worst case consideration) and the number of transport changes that one has to undergo. In case of Sundarban all of these three factors are again dependent on the season (navigable waterways) and the time of the day (occurrence of tides).

Thus the Accessibility Index between any two points computed in the commutation model varies inversely with the Distress Factor between them and combining this Distress Factor with the Commutation Details one can redefine Accessibility Index as Qualitative Accessibility Index.

Disease Constraint

The Disease Constraint model defines all the factors (both clinical and spatial) that must be met for treating the diseases with different level of criticality. This includes the allowable time (maximum) necessary to get a particular treatment, the condition of the road required to transfer the patient to the health center and the maximum number of transport changes or relocations that can be allowed.

The Referral (Computation) Model

The model is thematically multi-sliced with a combination of spatial and non-spatial slices intertwined on hierarchical information architecture. These slices are mostly conceptual. In terms of an implementation under a GIS system multiple slices are flattened into a few GIS layers for efficiency of storage, visualization and computation.

At the base slice there is a spatial layer. This is where the whole story starts and this is where the story should end as well. This layer has a set of node points – nodes representing the *Villages* (origins for patient) as Entry Points and also the nodes representing the *Health Centers, HC* (destinations for referrals) as Exit Points. Besides the Entry and Exit Points, this layer also marks the *Village Clusters* as GPs and represents the distinguishability or indistinguishability of every village in terms of the resolution for the referral.

The next slice is again a spatial layer that represents the routing information. It comprises node points (called *Intermediate Points* or IP) that are used for transiting from one mode of conveyance to another or from one route to the next. A typical IP is one of the following:

1. Bus Stops,
2. Ferry Ghat,
3. Villages and
4. HCs.

Besides IPs, this layer also has the road and river network for easy computation of connectivity and routing information. This connectivity information is annotated with day/night and seasonal information that affects the routes.

Overlaid on the same slice and registered with the connectivity is the information on various routes based on different modes of transport – bus, van, boat etc. This also provides the necessary commutation data (including fare and time of travel) required in the cost function.

Next couple of slices mostly maintains various non-spatial data that primarily act as constraints for feasibility of using a HC as a referral point for a patient-disease-condition point. The non-spatial information includes:

1. Available Facility at HC – the man-machine-medicine trio
2. Facility required to handle a disease /and or condition.
3. List of high occurrence diseases and conditions
4. Treatment conditions required for handling a disease or condition.

Process of Optimization / Constraint Satisfaction

We use iterative constraint satisfaction to refine from a global set of HCs with the repeated application of one or more sets of constraints. The idea is to first ensure that a HC under consideration must satisfy the basic requirements for service delivery for any case under consideration. Once the constraint satisfaction is achieved, we can have one of several situations:

1. No HC is left out in the viable satisfied set. We then have no solution. This should be rare. But as and when it happens, it would be a grave warning to the health system because it indicates that the system is unable to provide any treatment path of the village / disease combine.
2. Only one HC is left in the viable set. We know the unique referral and we are done.
3. More than one HC is retained. We then identify the cost components for optimization and compute the overall referral cost for each of the HCs. The one with the lowest cost is marked as the referral in this case.

In #3 above, we may optionally accept more than one best (least cost) solution. The final referral can then be selected based on human judgment using criteria that may not have been captured / modeled above.

CONCLUSION

It is indeed difficult to address the problems of public health care utilisation in the Sunderbans in totality, as it is extremely dependent on geophysical and natural conditions. Serious attempts are being taken to tackle some of the problems by providing supportive logistic facilities but a planning process in-building the conditioning factors is bound to strike the problem at the root and thus create a situation for improved utilisation through appropriately designed referral chains. Study of the referral and referred cases would reveal the degree of compliance with and utilisation of the referral mechanism and resulting improvement in morbidity status. The realistic referral chains may also give indications for facility allocation among different units depending on the service load.

Health department personnel with a simple to use GIS system would be better equipped to generate optimal referral chain and the degree of compliance to the designated referral chain would definitely improve. .

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